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Generation of Gate Pulses by Using Digital Signal Processor to Control the Speed of Three Phase Induction Motor in Code Composer Studio

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Abstract*:* Three phase induction motors are the most widely used motors for industrial control and automation. Hence they are often called the workhorse of the motion industries[1]. They are robust, reliable, less maintenance and of high durability. When power is supplied to an induction motor with recommended specified voltage and frequency, it runs at its rated speed. However many applications need variable speed variations to improve the quality of the product. The development of power electronic devices and control systems has to mature to allow these components to be used for speed control of AC and DC motors control in place of conventional methods. Apart from power electronics devices which are used to generate gate pulses we can use DSP kit to generate SPWM pulses. Firstly, the program for generating SPWM pulses for feeding the IGBT inverter is written in C Language using code composer studio and the TMS320F2812 processor is connected to the computer using USB Emulator[3]. The program is dumped to the TMS processor kit and executed. The SPWM pulses obtained at the output ports can be verified using CRO. These pulses are fed to the inverter module to drive the Three Phase Induction Motor.

Keywords: SPWM-Sinusoidal Pulse Width Modulation.

INTRODUCTION

Pulse Width Modulation variable speed drives are increasingly applied in many new industrial applications that require superior performance. Recently, developments in power electronics and semiconductor technology have lead improvements in power electronic systems. Three phase voltage-fed PWM inverters are recently showing growing popularity for multi-megawatt industrial drive applications. The main reasons for this popularity are easy sharing of large voltage between the series devices and the improvement of the harmonic quality Variable voltage and frequency supply to AC drives is invariably obtained from a three-phase voltage source inverter A number of Pulse Width Modulation (PWM) schemes are used to obtain variable voltage and frequency supply. The most widely used PWM schemes for three-phase voltage source inverters are carrier-based sinusoidal PWM. Three phase induction motors are most widely used motors for any industrial control and automation. It is often required to control the output voltage of inverter for the constant Voltage/Frequency (V/F) control of an induction motor[4].

Three-phase squirrel-cage induction motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with Variable-Frequency Drives (VFDs) in variable-speed service[5]. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and VFD applications.

Signal Processing is a very mathematically oriented and intensive area forming the core of digital signal processing and it is rapidly expanding with new applications in every field of electrical engineering such as communications, control, radar, TV/Audio/Video engineering, power electronics and bio-medical engineering as many already existing analog systems are replaced with their digital counterparts. Digital Signal Processing both provides a mathematical description of the systems to be designed and also actually implements them (either by software programming or by hardware embedding) without much dependency on hardware issues, which exponentiates the importance and success of DSP engineering[6].

With Digital Signal Processors (DSPs) getting some serious consideration for use in controlling power supplies, the embedded systems designer needs to address a number of pertinent factors in the design and implementation of a digital control loop. For one thing, accurate representation of the control blocks and the associated control parameters is

critical for the analog designers in order to enable them to implement the DSP based digital control techniques using the well-known analog control design approaches.
Digital controllers are also less susceptible to aging and environmental variations and have better noise immunity. Moreover, a modern 32-bit DSP controller, such as TMS320F280x, with their real-time code debugging capabilities, give the power supply designers all the benefits of digital control and allows implementation of high bandwidth, high frequency power supplies without sacrificing performance[6]. The extra computing power of such processors also allows implementation of sophisticated nonlinear control algorithms, integrate multiple converter control into the same processor and optimize the total system cost.

II. ISSUE CONTENT

Induction motors are semi synchronous. They want to turn at the same rate of the line frequency (for a standard 2-pole motor that is 3600 RPM (for 60 Hz) at no load. The Slip occurs as the torque is increased; at full load the motor will have slipped about 5-10% or about 3400 RPM. So in a fixed frequency system, the rate of the rotating field determines the speed, less the torque induced slip.So voltage does NOT control the speed directly.It's not that hard to control the speed; it requires a variable frequency AC drive, which is however, more complex than a variable voltage drive. In a synchronous motor, we generate the rotors electrical field through a commutator. This electrical field is the basis for contrasting the stator field and creating magnetic fields and creating movement. The advantages here are they run exactly what you tell them to run until failure. We use these for items that require precise positioning or precise metering. But these are expensive, and require brushes on a commutator which require more maintenance. A cheaper version is the induction motor because there's no link between the rotor and the drive. Induction motors generate their rotor field by electronically inducing a current from the moving stator field into the rotor. As the field of the stator rotates around the rotor, it's difference in speed induces a field in the rotor windings causing the rotor to want to follow the stator field, lagging behind. It can never catch up because if it did that would bring induced rotor voltage to 0 and it would stop again.
So induction motors require lagging behind their generated field to induce a current. This lag changes with load and speed. So the motors are inherently more difficult to control accurately. Newer technology in VFD's have come up with slip compensation that can accurately compensate. This is through known testing data on motors of known load. It incorporates this into the drive and helps make control almost as accurate as a synchronous motor. Coupled with a high-resolution encoder and you can have some pretty accurate motor control.

III.THE SOLUTION APPROACH

A.V/F Control

Whenever three phase supply is given to three phase induction motor rotating magnetic field is produced which rotates at synchronous speed given by

$$N_S=\frac{120\ F}{P}$$

In three phase induction motor emf is induced by induction similar to that of transformer which is given by

$$\phi=\frac{V}{4.44KTF}$$

Where ,
K is the winding constant,
T is the number of turns per phase and
f is frequency.
Now if we change frequency synchronous speed changes but with decrease in frequency flux will increase and this change in value of flux causes saturation of rotor and stator cores which will further cause increase in no load current of the motor[1] . So, it's important to maintain flux , φ constant and it is only possible if we change voltage i.e.., if we decrease frequency flux increases but at the same time if we decrease voltage flux will also decease causing no change in flux and hence it remains constant. So, here we are keeping the ratio of V/ f as constant. Hence its name is V/ f method

B. Control Of Induction Motor Drive

The majority of Asynchronous Machine drives are based on (voltage/frequency) ratio control operation with a three phase inverter. The torque developed by the induction motor is directly proportional to the ratio of the applied voltage and the frequency of supply[2]. Control is achieved by varying the voltage and the frequency, but keeping their ratio constant, throughout the speed range.
Other than the variation in speed the torque-speed characteristics of the control from Fig 1 reveals the following.
The starting current requirement is low.

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2. The stable operating region of the motor is increased.
3. The motor can be made to operate from 5% of the synchronous speed up to the rated speed .The torque generated by the motor can be kept constant throughout this region. Hence it is called as constant torque region. At the rated speed, the voltage and frequency reach the rated values and delivers rated torque.
The motor can be operated beyond the rated speed by increasing the frequency further. Because of the insulation problems, the applied voltage cannot be increased beyond the rated voltage, hence it is called constant power region. Therefore, only the frequency can be increased, which results in the reduction of torque. Above the rated speed, the factors governing torque become complex.
5. The acceleration and deceleration of the motor can be controlled by controlling the change of the supply frequency to the motor with respect to time. At rated speed, when the load is increased, the speed drops and slip increases. The motor can take up to 2.5 times rated torque with around 20% drop in speed. Any further increase of load on the shaft can stall the motor.
6.The torque developed by the motor is directly proportional to the magnetic field produced by the stator. So the voltage applied to the stator is directly proportional to the product of the stator flux and angular velocity. This makes the flux produced by the stator proportional to the ratio of applied voltage and frequency of supply. By varying the frequency, the speed of the motor can be varied.
7.Therefore, by varying the voltage and frequency by the same ratio, flux and hence the torque can be kept constant throughout the speed range. This makes constant the most popular method of speed control of the induction motor.

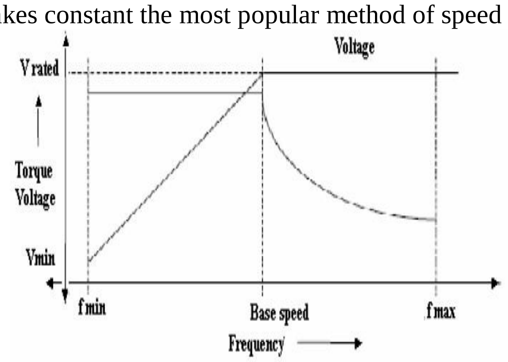

Fig1: V/F characteristics of Induction motor

C. Inverter
A device that converts DC power into AC power at desired output voltage and frequency is called an Inverter. Inverters can be broadly classified into two types based on their operation:
Voltage Source Inverters(VSI)
2. Current Source Inverters(CSI)
Voltage Source Inverters is the one in which the DC source has small or negligible impedance. In Other words VSI has stiff DC voltage source at its input terminals, as shown in the figure 2. A current source inverter is fed with adjustable current from a DC source of high impedance, i.e., from a stiff DC current source.

Based on the connections of semiconductor devices, inverters are classified as under follows
1.Bridge Inverters
2. Series Inverters
3.Parallel Inverter
Here the three phase full bridge voltage source inverter is used. The bridge can be made using IGBTs which are controlled by control signal.

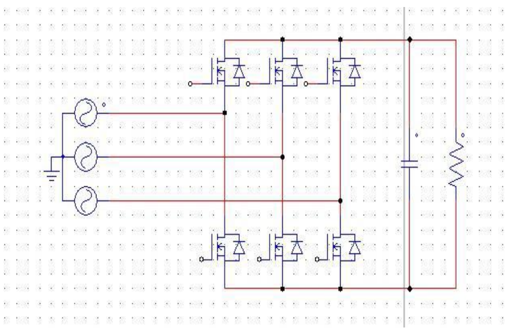

fig 2: 3-phase voltage source inverter bridge

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D. DSP Processor

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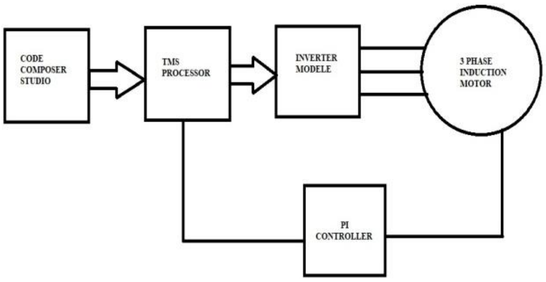
Digital Signal Processing both provides a mathematical description of the systems to be designed and also actually implements them (either by software programming or by hardware embedding) without much dependency on hardware issues, which exponentiates the importance and success of DSP engineering. With Digital Signal Processors (DSPs) getting some serious consideration for use in controlling power supplies, the embedded systems designer needs to address a number of pertinent factors in the design and implementation of a digital control loop. For one thing, accurate representation of the control blocks and the associated control parameters is critical for the analog designers in order to enable them to implement the DSP based digital control techniques using the well-known analog control design approaches.

Digital controllers are also less susceptible to aging and environmental variations and have better noise immunity. Moreover, a modern 32-bit DSP controller, such as TMS320F280x, with their real-time code debugging capabilities, give the power supply designers all the benefits of digital control and allows implementation of high bandwidth, high frequency power supplies without sacrificing performance[5]. The extra computing power of such processors also allows implementation of sophisticated nonlinear control algorithms, integrate multiple converter control into the same processor and optimize the total system cost.

D. Block Diagram

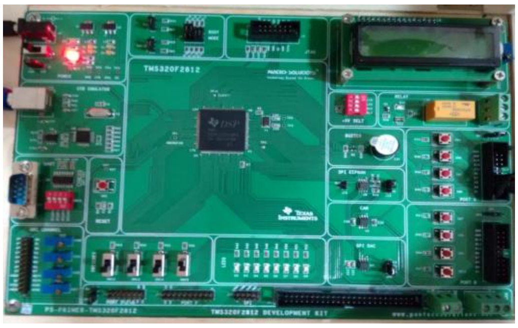


A DSP Processor is generating SPWM pulses. Firstly, the program for generating SPWM pulses for feeding the IGBT inverter is written in C Language using code composer studio and the TMS320F2812 processor is connected to the computer using USB Emulator[6]. The program is dumped to the TMS processor kit and executed. The SPWM pulses obtained at the output ports can be verified using CRO. These pulses are fed to the inverter module to drive the Three Phase Induction Motor.

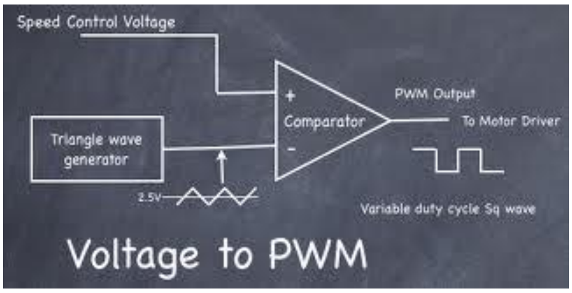
E. Code Composer Studio

Code Composer Studio Integrated Design Environment for the C2000 Family of Texas instruments Digital Signal Processors. Simply, Code Composer Studio is the environment for project development for all tools needed to build an application for the C2000-Family. The objective of this module is to understand the basic functions of the Code Composer Studio v4, how to create and debug a project in CCS v4 for TMS320F2812/F28335 kit. This following section will introduces some of the basic features and functions in Code Composer Studio so you can create and build simple projects. Experienced users can proceed to the following sections for more in-depth explanations of Code Composer Studio's various features.

F.TMS320F2812 Processor



G.PWM Waveform Generation



Up to eight PWM waveforms (outputs) can be generated simultaneously by each event manager: three independent pairs (six outputs) by the three full-compare units with programmable dead bands, and two independent PWMs by the GP-timer compares.

V. Root Locus Technique To Tune The Pi Controller

To determine the values of PI Controller we first determine the transfer function of Induction motor by modeling the Induction machine[6]. In drive operation, the speed ωr can be controlled indirectly by controlling the torque which, for the normal operating region, is directly proportional to the voltage to frequency. The torque T given by equation also:

$$T_e = 3\left(\frac{P}{2}\right)\left(\frac{V_s}{\omega_e}\right)^2 \frac{\omega_{slm} R_r}{R_r^2 + \omega_{slm}^2 L_{lr}^2}$$

by

T_e is developed torque $(N \cdot m)$

P is pole of induction motor

ω_e is stator supply frequency (rad/s)

$\omega_{slm} \cdot l_{lr}$ is leakage reactance (Ω)

R_r is rotor resistance (Ω)

V_s is input voltage per phase $(Volt)$

The machine torque and speed are related by the following equation

$$J\frac{d\omega_r}{dt} + B\omega_r = T_e - T_L$$

by

J is moment of inertia

B is viscous friction

T_L is load torque $(N \cdot m)$

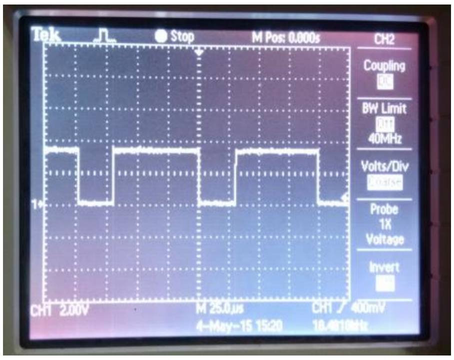
From relationship FROM THE ABOVE equationS transfer function of induction motor for speed control is

$$\frac{\omega_r}{V_s} = \frac{K}{Js + B}$$

by K is $3\left(\frac{P}{2}\right)\left(\frac{1}{\omega_e}\right)^2 \frac{\omega_{slm} R_r}{R_r^2 + \omega_{slm}^2 L_{lr}^2}$

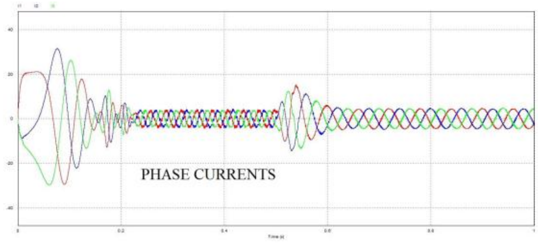
IV RESULTS

A. The Sinusoidal Pulse width Modulated signals obtained from the TMS processor kit are as follows:



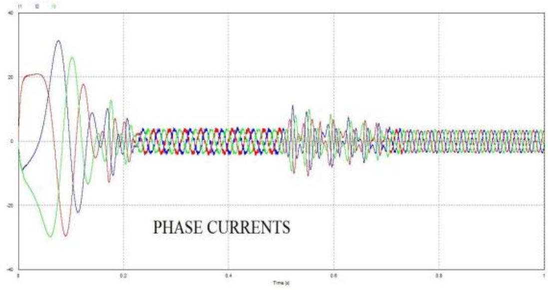
B. High Speed to Low Speed Profile

C. High Speed to Low Speed Phase Current Profile



D. Low Speed to High Speed Profile

E. Low to High Speed Phase Current Profile



V.CONCLUSION

Apart from power electronics devices which are used to generate gate pulses we can use DSP kit to generate SPWM pulses. Firstly, the program for generating SPWM pulses for feeding the IGBT inverter is written in C Language using code composer studio and the TMS320F2812 processor is connected to the computer using USB Emulator. The program is dumped to the TMS processor kit and executed. The SPWM pulses obtained at the output ports can be verified using CRO. These pulses are fed to the inverter module to drive the Three Phase Induction Motor.

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